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TECHNICAL REPORT NO. LWL-CR-21C73

MODEL STUDY OF INSTANT VEHICULAR CAMOUFLAGE

Final Report

Contract No. DAAD05-73-C-0140

By

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October 1973

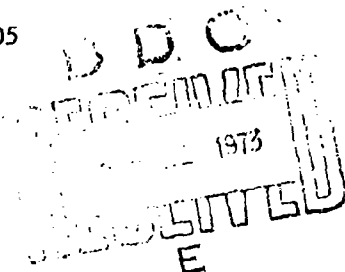


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U.S. Army Land Warfare Laboratory

Aberdeen Proving Ground, Maryland 21005



FOREWORD

This report is submitted in compliance with contractual requirements as directed by the U.S. Army Land Warfare Laboratory, Aberdeen Proving Ground, Maryland, under Contract No. DAAD05-73-C-0140. Mr. Joe Swisher, Applied Chemistry Branch, served as Technical Supervisor for the work, and we would like to acknowledge his insights and assistance during the project.

Principal Investigators for the program at The Franklin Institute Research Laboratories were Mr. Peter Bressler, Research Engineer and Mr. John DeBenedictis, Manager, Optics and Electronics Laboratory.

This program was funded by the Camouflage Lead Laboratory, U.S. Army Mobility Equipment Research and Development Laboratory, Fort Belvoir, Virginia; Project No. 1G663702D471-01.

Some of the concepts described in this report, especially those detailed in the Appendix, may not appeal to the pragmatic mind or lack credible field applicability. They are all presented, however, as evidence of the broad possible scope of materials and concepts applicable to camouflage and for the inspiration they may provide the reader in applying some - to him - obvious practical variation to solve a user need.

ABSTRACT

Under Work Assignment No. 5 of Contract No. DAAD05-73-C-0140, The Franklin Institute Research Laboratories conducted a best effort feasibility study to determine what materials and geometric systems would be required for fabrication of a camouflage system that would instantaneously cover a military vehicle in order to disrupt its characteristic shape or outline.

The program involved intensive research and field trips in which the state-of-the-art of modern camouflage was studied; conception of numerous camouflage systems from the research and group synetics* process; production of prescribed models and diagrams; and analysis of systems and conclusions as to their feasibility.

* The study of creative processes especially as applied to the solution of problems by a group of diverse individuals.

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1. INTRODUCTION

This report is the conclusion of a best effort feasibility study to determine what materials and geometric systems would be required for fabrication of a camouflage system that would instantaneously cover a military vehicle in order to disrupt its characteristic outline or shape. The process involved intensive research and field trips in which the state-of-the-art of modern camouflage was studied; conception of numerous camouflage systems from the research and group synetics process; production of prescribed models and diagrams; and analysis of systems and conclusions as to their feasibility.

In order to innovate and evaluate a camouflage system or systems, some basic state-of-the-art research must be performed. Our original trip to LWL provided a great deal of conceptual material. A subsequent research trip to the Mobility Equipment Research and Development Center at Fort Belvoir, Virginia, provided access to a large library of camouflage techniques. During this visit, numerous slides of typical Maryland landscapes and potential camouflage positions were taken to determine the exact nature of available foliage for the purpose of constructing a demonstration model. A conference was held with a local professional magician to discuss his techniques which might prove useful in camouflage. A group of imaginative scientists, engineers and technicians were assembled to "brainstorm" all concepts. Artists conceptions of these ideas are presented in Appendix A. From this research and other source material, such as Department of Army Field Manual FMS-20 "Camouflage" and Department of the Army Technical Manual TMS-200 "Camouflage Materials", we gleaned the following four basic camouflage concepts presently in use:

1. Cut Foliage - freshly cut foliage is spread over and secured to the vehicle to disrupt its shape, change its appearance to more apparently blend with its environment.
2. Nets - cut nets of either garnished, pattern, or cut strand and/or chicken wire draped over umbrellas-like structures or directly over the vehicle to change the shape.
3. Pattern Painting - the vehicle is painted in irregular patterns (more natural in form) to destroy the visually alien man-made structures. Appropriate colors as well as infrared paints are used.
4. Decoy - construction of a decoy structure to attract the viewer's attention away from the strategic vehicle.

2. PROCEDURES

During a three hour synetics session a great number of new camouflage systems were envisioned. During the subsequent analysis, the model called for by the task report was fabricated. A diorama in a suitcase-like carrying box, a 1/35th scale ½ ton 4x4 jeep, and a 1/35 scale M60 tank were fabricated for the purpose of illustrating camouflage techniques. Also supplied is a landscape typical of a Maryland scene in summer months, camouflage models, slides of Maryland and slides demonstrating camouflage effectiveness. It should be noted that several camouflage systems that are entirely feasible in reality lose a great deal of credibility when scaled by 1/35th due to actual materials limitations. The various camouflage systems tried and/or suggested and illustrated in the accompanying slides are described as follows:

1. Foam Netting - deployment from a small cannister, mounted on the vehicle, of a super low density, large pore size, open cell foam net of a strong enough plastic, such a polypropylene, so as to be self-supporting. Because of its low density and high strength a large area could be covered without actual net draping or "umbrella points".
2. Foam Foliage - a very low density, high resilience foam, precolored and shaped like bushes would be compressed into small containers (perhaps magnetically attached to the vehicle). On command, the container would open enabling the compressed foam to expand to its normal form obscuring the vehicle and changing its shape.
3. Inflatable Foliage - pneumatic structures of various materials printed and cut to resemble trees and foliage could be rolled up and/or stuffed into containers like small bore ammunition boxes and inflated upon command by CO₂ cartridge, compressed air, or manually.
4. Inflatable Reflector - a reflective barrier of metallized vinyl could have an integrally designed inflatable structure that when inflated would automatically unfold or unroll and support itself.
5. Inflatable Nets - a net of standard configuration could have an integral pneumatic structure as described above.
6. Inflatable Barriers - an actual camouflage balloon like barrier that would be inflated between the vehicle and the observer.
7. Plastic Foliage Kits - employing modern plastic technology to produce actual injection molded foliage to resemble that of the environs. This could be constructed with "pop-it" like joints so as to be assembled and attached to vehicles.
8. Spring Loaded Foliage - a system similar to the one above, however, preassembled and compressed in a container with spring steel wire stems. On command the open container would permit the branches to "pop up". This is a typical stage magician modus operandi.

3. RECOMMENDATIONS

Of the list in Section 2, the following priority is set in relation to feasibility:

1. Inflatable foliage would create the most realistic foliage cover available. Using pneumatically supported "stems" and injection molded or cut vinyl leaves, colored appropriately, deflated into magnetic or mechanically attached containers, a vehicle could literally carry a stand of trees at the ready, independent of terrains. It would unroll or expand through use of CO₂ cartridges, hand pumps, footpumps or breath.
2. Pneumatically supported nets would appear to be the simplest solution in relation to present camouflage methods. A heat sealed vinyl sheet pneumatic support structure could easily be designed to be comparable to the vinyl and plastic string nets available. When not in use the net would be secured in a rolled or "reefed" position to the side of the vehicle. Inflation methods would be used as above.
3. Spring Loaded Foliage employs plastic molding methods used to create artificial flowers combined with spring steel "stems" compressed into small containers located arbitrarily over the body of the vehicle. This would provide more realism than is presently available.
4. Foam Foliage would perform similarly to inflatable foliage and would tend to be less expensive. It would, however, probably not be as realistic in appearance. It would not need to be inflated as the foam's "memory" would activate it once released.
5. Plastic Foliage Kits would give the same realistic and long life as the above systems, however would probably take longer to assemble and disassemble.
6. Pneumatic Reflection would function similarly to the pneumatic net supports, however, would be subject to those limitations inherent in a reflection system.
7. Foam Nets would do as good a job as present netting and not need the bulky, heavy support devices. However, its make-up would not provide the close proximity cover inherent in other systems. It would be very inexpensive to manufacture.
8. Inflated Barrier system is merely the inflation of a shaped balloon to obscure the vehicle. It could, however, serve as a decoy function, i.e., inflatable tank or jeep.

4. DISCUSSION

Figure 1 shows an artist conception of how the inflatable foliage would operate. A box mounted on a bumper(s) or other strategic areas would house the inflatable foliage as well as a gas cannister and aspirator if needed. An extension cable would allow the driver to activate the inflation mechanism. The expanding foliage would release the cover so that a driver by himself can be fully protected in a matter of seconds. The foliage is designed as a silhouette interruptor so that the vehicle maintains the option of mobility. As the artist conception shows, vinyl sheet could be used to fabricate the foliage. This would allow a larger selection of colors and enable easy construction. Heat sealing techniques would make the stems air tight and a random pattern cut for leaves could be easily employed for realism. "Leaves" would blow in the breeze as real foliage does. (only stems would be inflated)

A kit was constructed to demonstrate various camouflage concepts. Figures 2 through 7 show a number of schemes.

Figure 2 shows the carrying case closed and open as well as a model of a tank and a foam dome covering a jeep.

Figure 3 depicts an inflatable vinyl net for quick deployment. Note especially the convenient mounting scheme for a tank. Of course, nets could be supplied for all sides.

Figure 4 shows inflatable foliage. In scale, it is difficult to control the shape and color of the balloon but in reality the inflating structure would be designed to deploy the foliage appropriately. Figure 5 depicts terrain reflectance. The concept has been demonstrated to work under favorable conditions. Logistics present a problem which would be minimized with an imaginative inflating system. Figure 6 shows foam foliage. The foam is manually pushed into a relatively small container.

(Perhaps 50 gallon drum for a tank). Release results in expansion to about 50 times its volume. Figure 7 shows a similar concept except it is in the form of a net. A storage cylinder of 1 foot diameter and 3 foot length would suffice for sufficient material to cover a tank.

Figure 8 shows an artist conception of inflatable nets which would allow easy storage and deployment capable of protection against aerial detection as well as ground detection.

Figure 9 depicts a similar scheme for selective barriers.

The basic concepts of camouflage are useless without an appropriate deployment scheme. Fairchild Space & Electronics Division, Germantown Maryland has extensive experience in Space Deployable Booms. Their expertise is very germane to further efforts in camouflage. Figures 10, 11 and 12 show some of their capabilities and concepts. Inflation techniques supported by this report would be enhanced with inputs from technology available at Fairchild.

Another related area is the concept of short antennas. Detection probability is enhanced by antennas protruding high above vehicles. Fairchild has ingenious methods to retract and deploy antennas. In addition, FIRL is cognizant of new concepts in antenna design. The need for long antennas is for transmitting. FIRL could provide an antenna system which would be extremely short for the receiving mode. When one wishes to transmit, he needs only to deploy the short antenna via Fairchild schemes. It is feasible to have an antenna deploy and retract in seconds using available battery power.

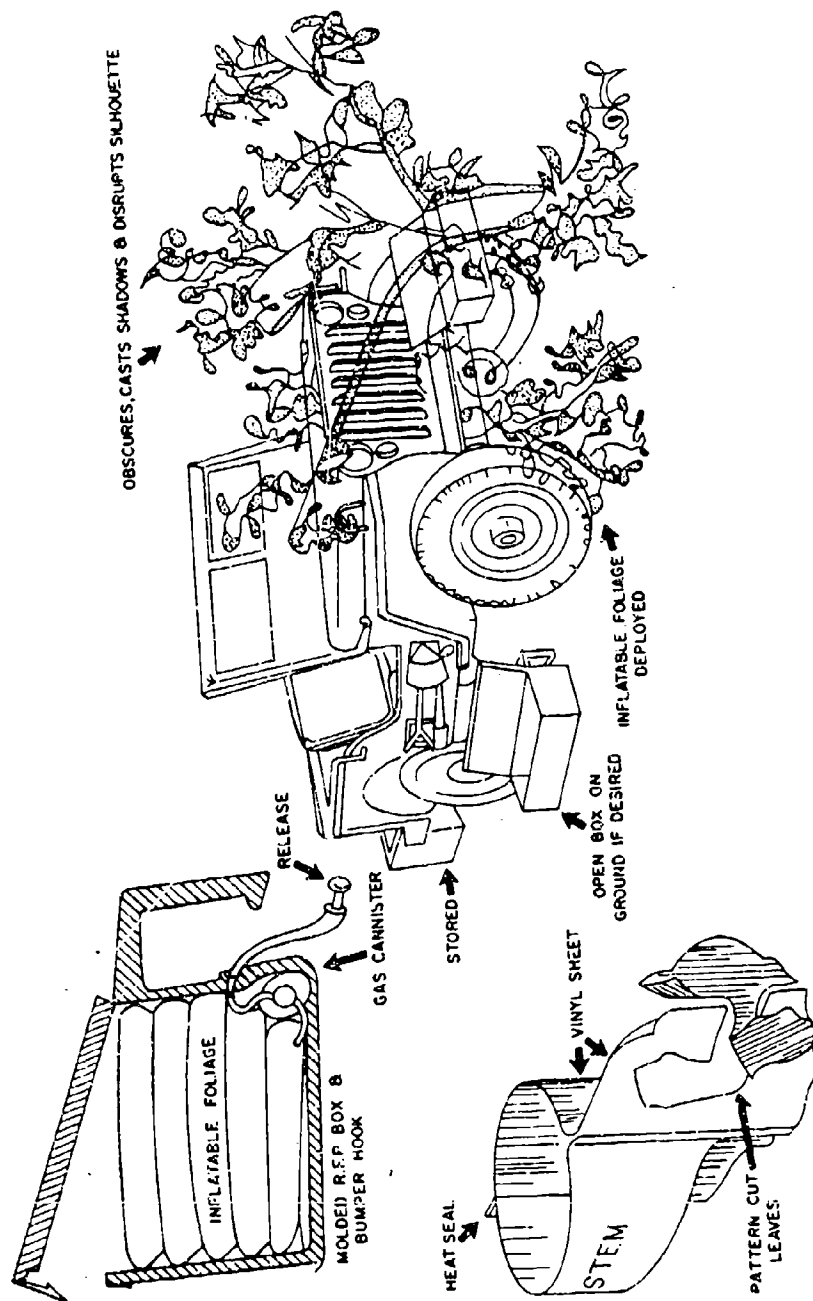


Figure 1. Operation of Inflatable Foliage



Figure 2. Carrying Case: Closed-Case Opened Tank View-Foam Dome



Figure 3. Vinyl Net: Inflatable Supports for Quick Deployment



Figure 4. Inflatable Foliage: Ballooning Structure Would be Geometrically Controlled and Painted Appropriately.



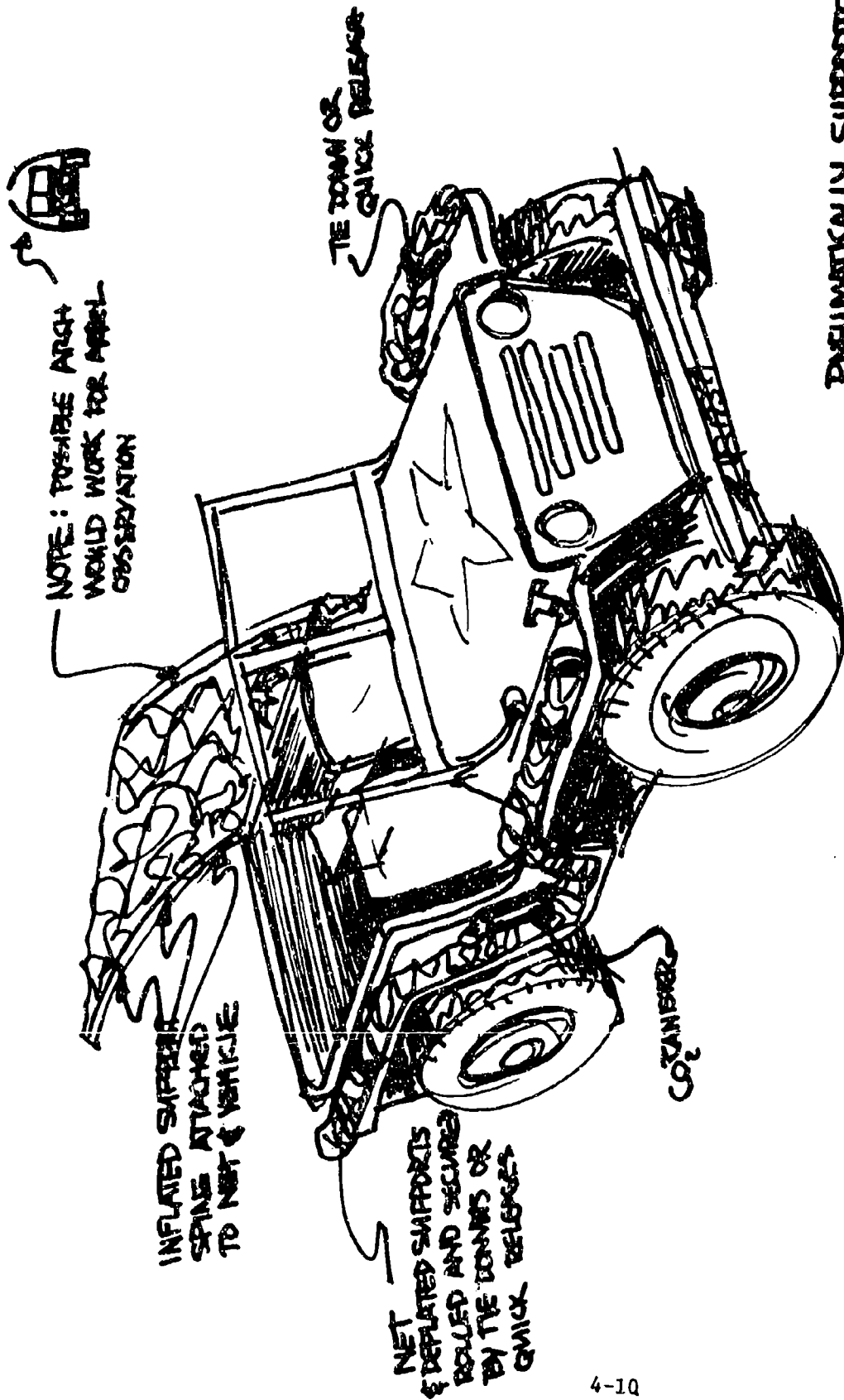
Figure 5. Terrain Reflectance: Inflatable Supports to Hold Reflective Material



Figure 6. Foam Foliage: Designed to look like Natural Foliage.
Stows in Volume Approximately 1/56th Expanded Volume.



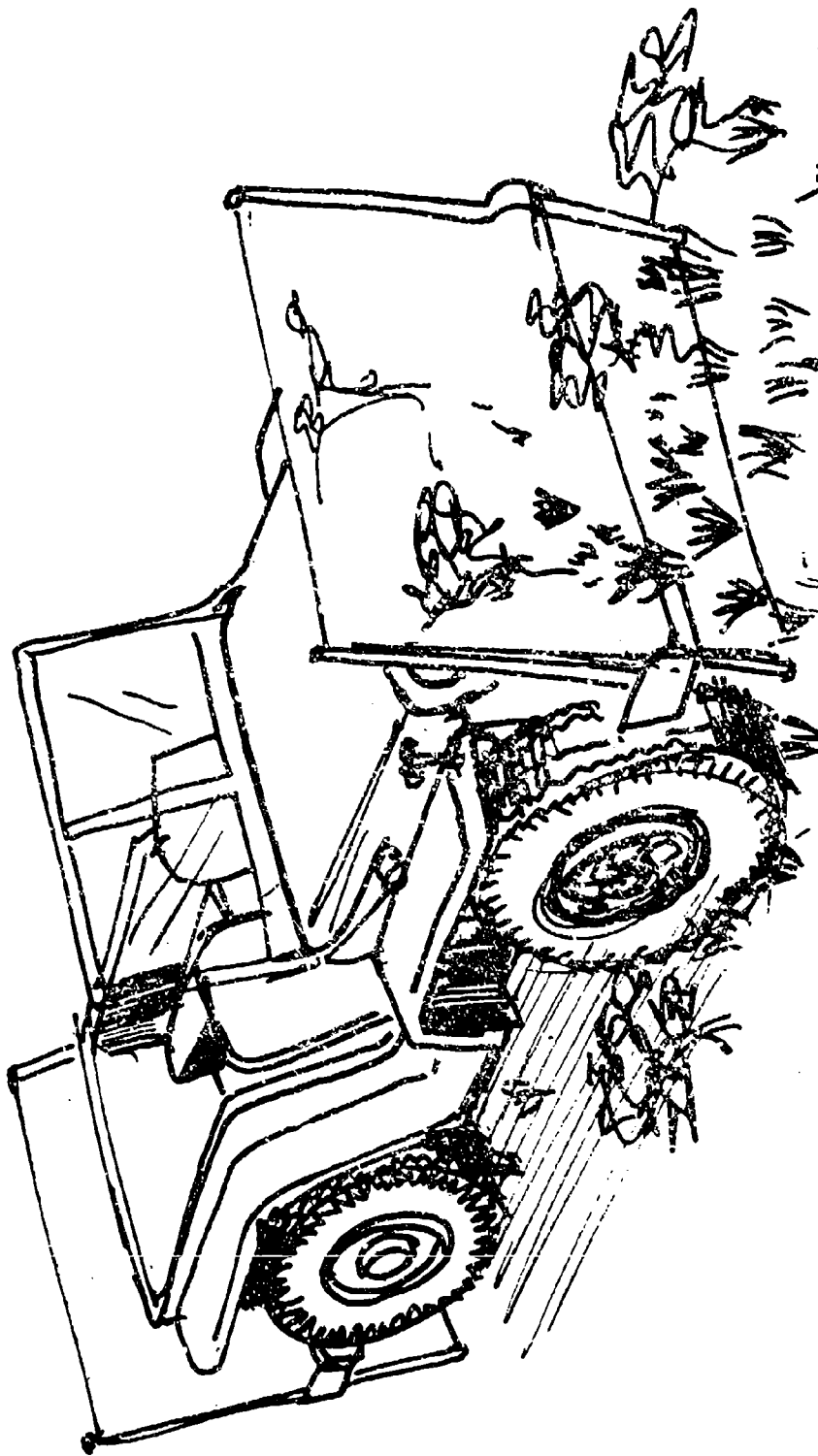
Figure 7. Foam Net: Stows in Container Approximately 1 ft Diameter and 3 ft long. Expands to Cover one end and one side of Tank



PNEUMATICALLY SUPPORTED AND DEPLOYED VINYL NETS

Figure 8. Pneumatically Supported and Deployed Vinyl Nets.

PMB



REFLECTIVE BARRIER IS
DISPENSED AND SUPPORTED
BY "FAIRCHILD SPACE BOOMS"
MOUNTED ON BUMPERS

Figure 9. Reflective Barrier Dispensed and Supported by "Fairchild
Space Booms" Mounted on Bumpers

FAB

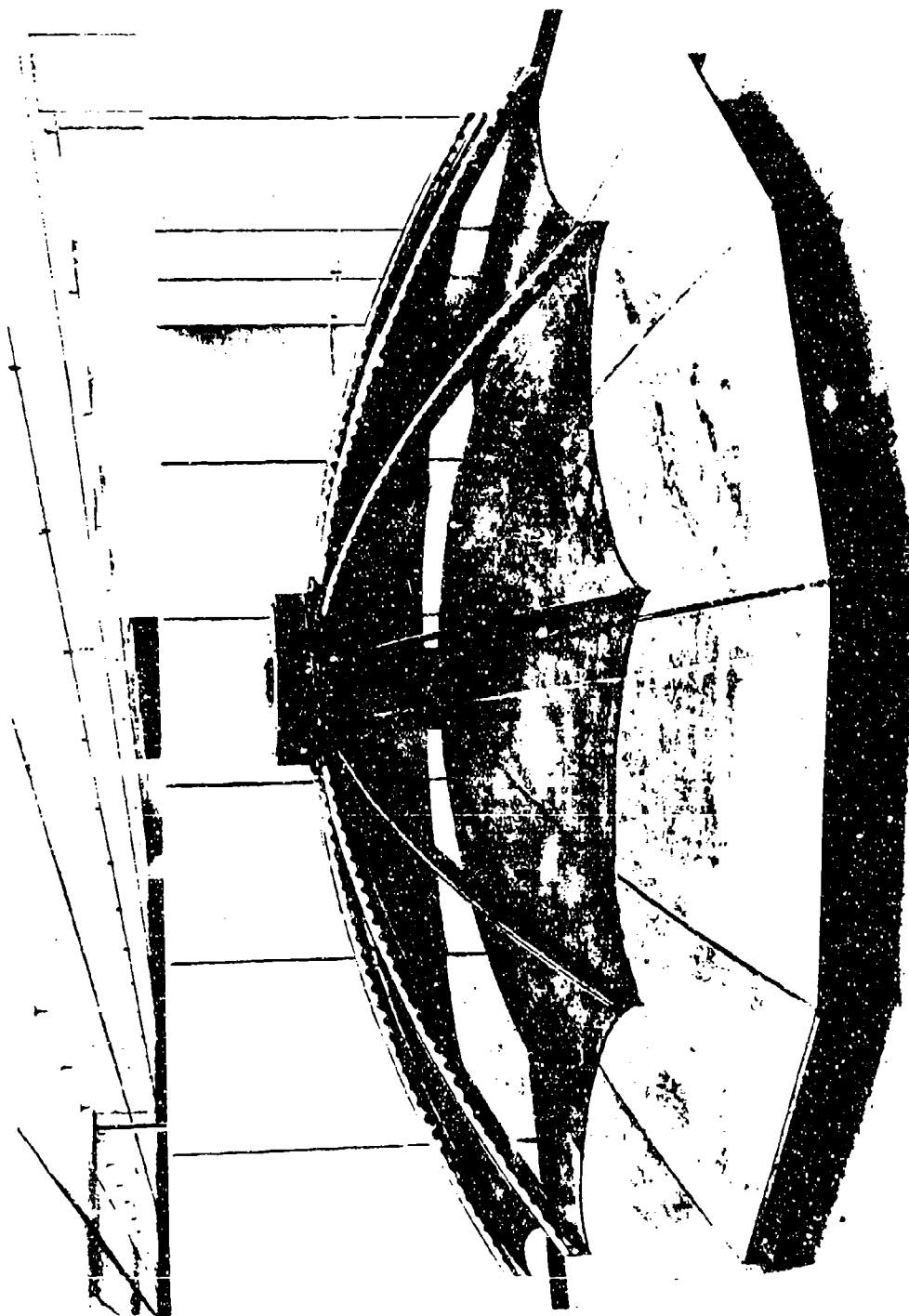


Figure 10. Fairchild Space Deployable Boom Capability and Concept.

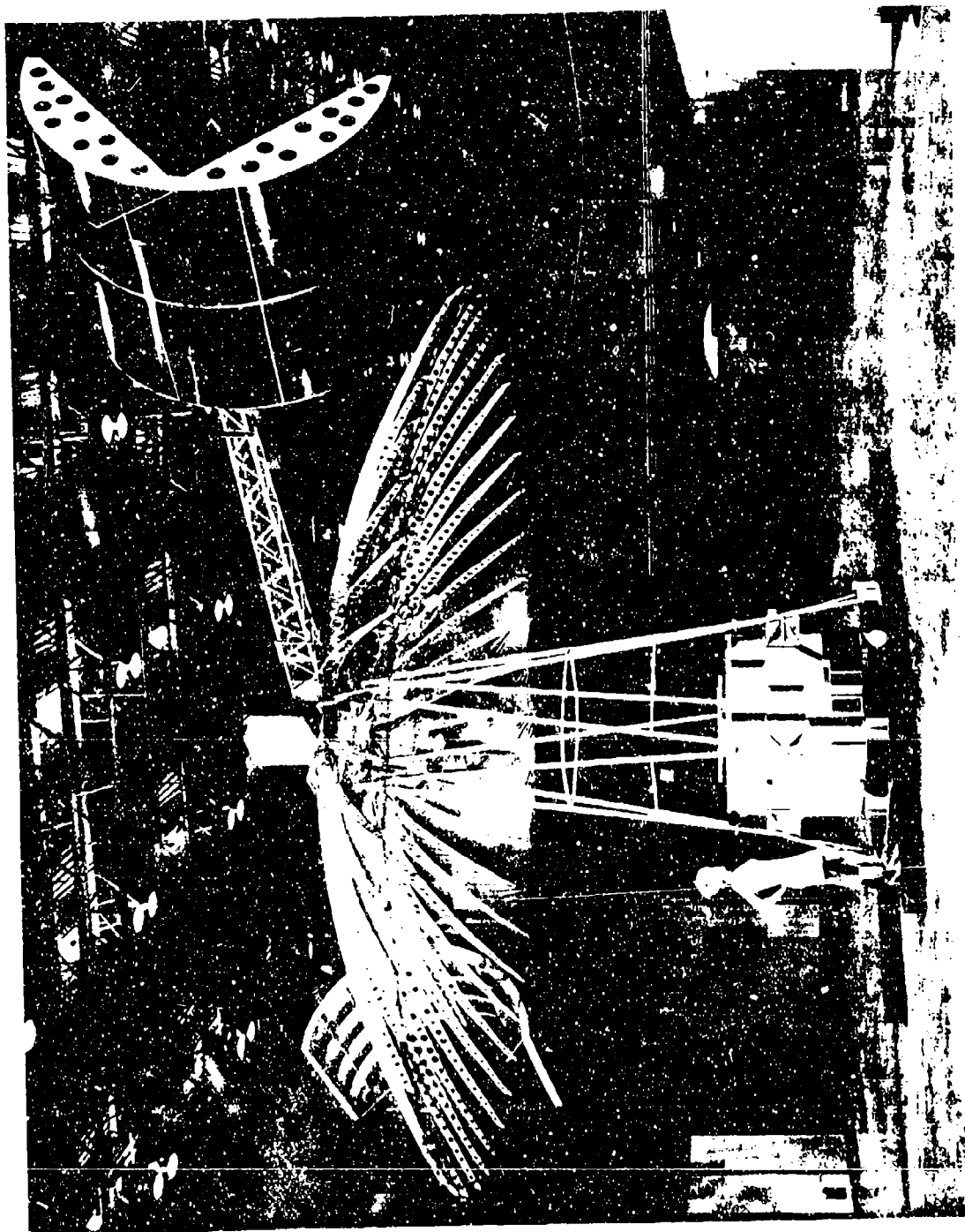


Figure 11 Fairchild Space Deployable Boom Capability and Concept.

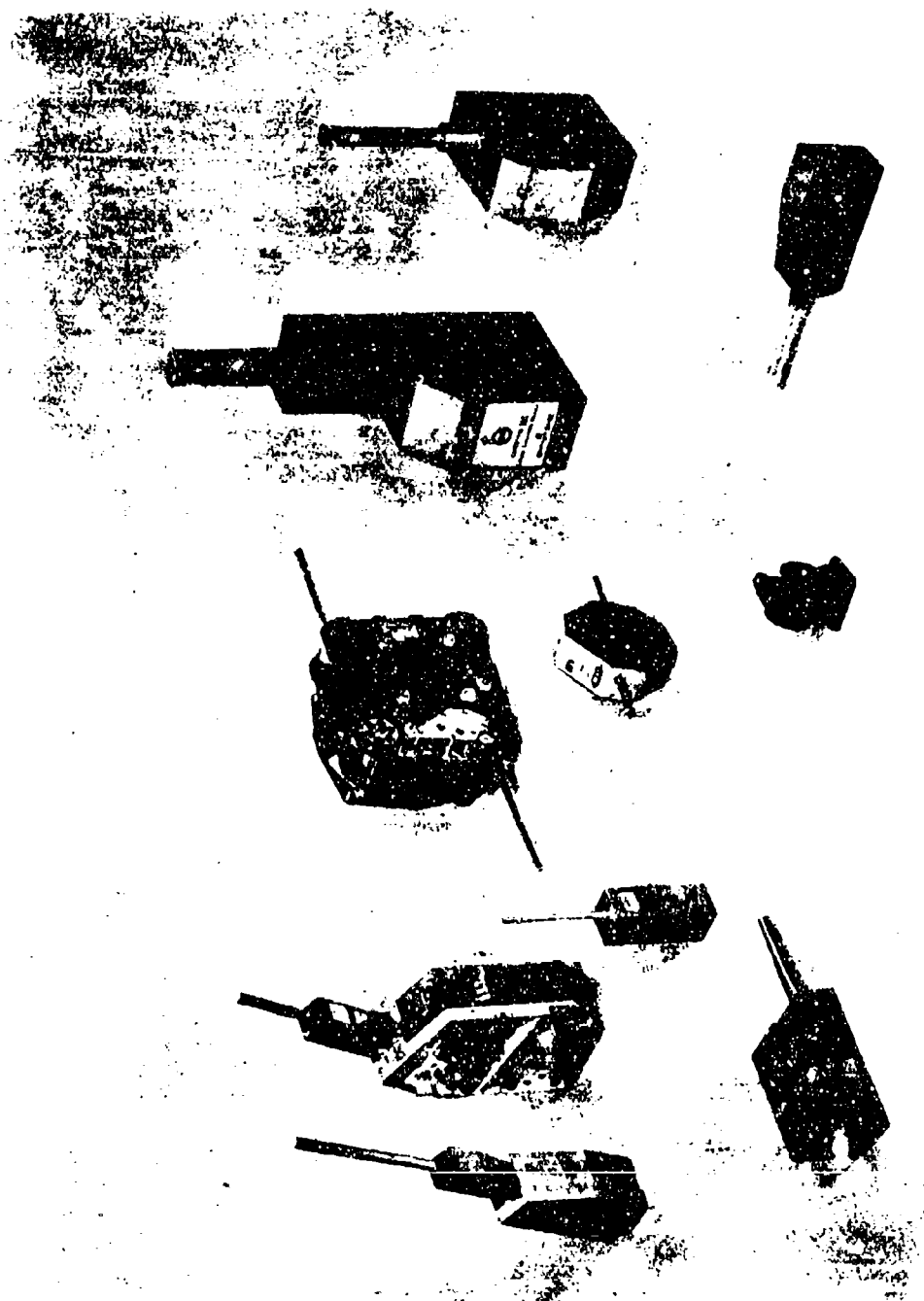


Figure 12. Fairchild Space Deployable Boom Capability and Concept

5. CONCLUSIONS

In conclusion, it is submitted that several, if not all, of the above systems would provide feasible instantaneous camouflage. With proper development, design and testing several alternative systems could be provided that would be of considerable improvement over camouflage presently being used.



Appendix

A

CAMOUFLAGE CONCEPTS



THE FRANKLIN INSTITUTE RESEARCH LABORATORIES
THE BENJAMIN FRANKLIN PARKWAY • PHILADELPHIA PENNSYLVANIA 19103

APPENDIX A

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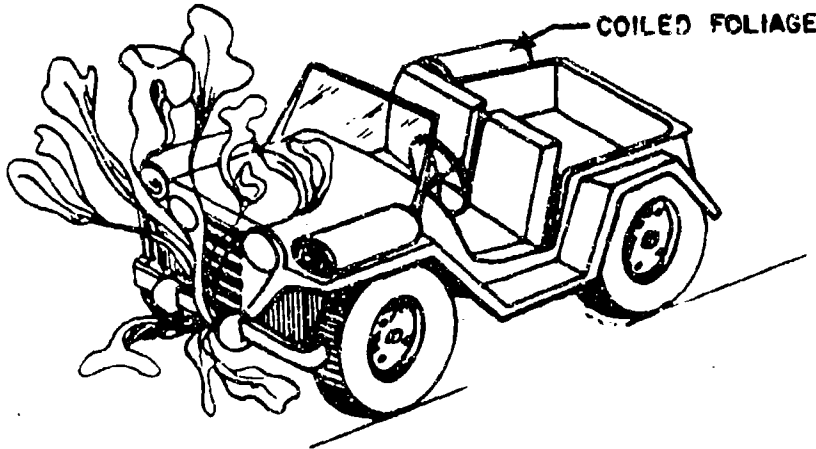
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Inflation Foliage

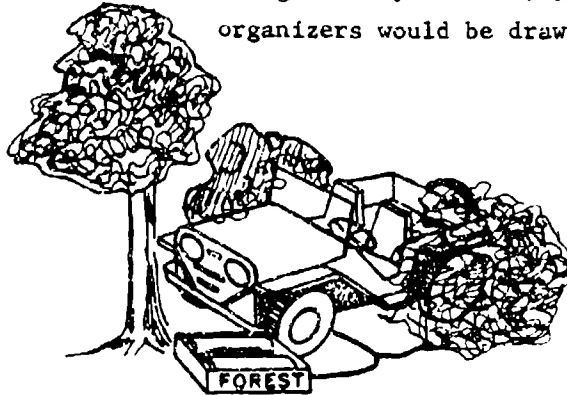
Inflatable materials could be used to break up the silhouette. These materials could be permanently located at strategic places. For instance, at sharp corners a package containing a "rubber bush" could be compactly stored and inflated either by a local cannister of compressed air or by a central compressor activated upon demand. This compressor would service all remote locations via tubing.



A built-in wire coil skeleton would automatically reroll the instant camouflage into a compact package as the inflation pressure is released.

Inflatable Forest

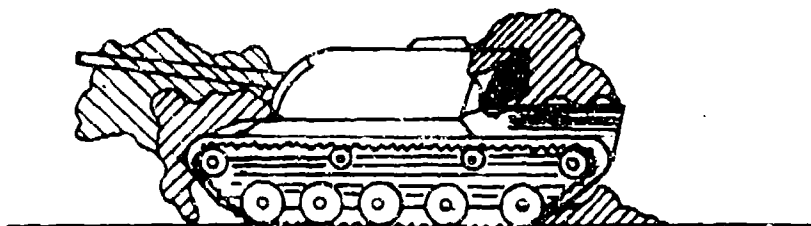
An "inflatable forest" could be stored on most vehicles without interference to their primary mission. State-of-the-art aspirators and compressed gas cannistors would suffice. The expertise of the special effects crew at leading movie producers, professional magicians and parade organizers would be drawn upon.



Rocks, boulders, hills, sand dunes, etc. could all be created in the same manner. The items could be deflated and repackaged or because of their low cost could be left behind in an emergency evacuation.

Contour Foams and Redesign

Foams could be used to break up straight edges and sharp corners. They could be applied in strategic places. Future design of combat equipment should keep this approach in mind. Skillful design would provide difficult silhouettes to detect.

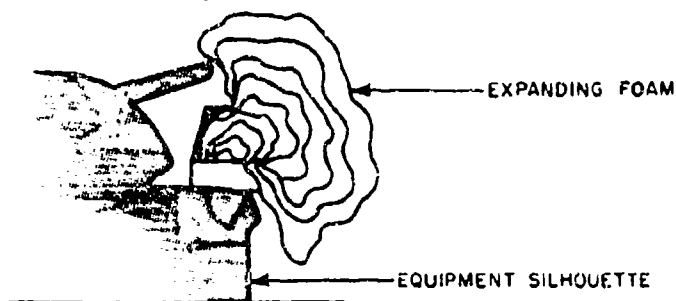


Shaded portions represent addition of foam. There appears to be no intelligent reason for equipment to be designed with straight edges. Spray foam would circumvent the problem on current generations of equipment.

The space between the undercarriage and the ground is a source of detection. Vehicles should be designed to have a lower profile (or at least cover this area) and could be equipped with recirculating ball screws to lower the vehicle to the ground in a stationary position.

Foam Foliage

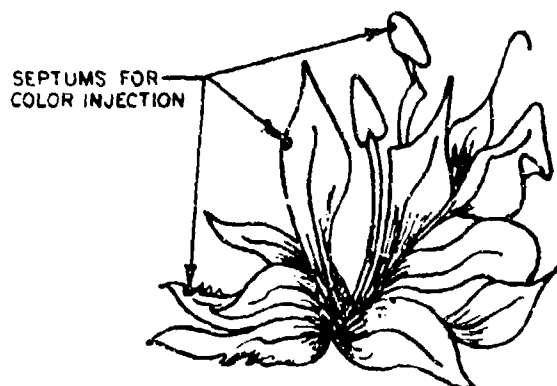
Small compartments could house a compactable foam replica of any foliage desired. The compartment would be magnetically attached to the equipment of interest. Release of a small clip or snap will allow the foam to expand and assume its shape. It would repackage by merely stuffing it back into the box.



Many childrens indoor games use this type of foam for basketballs, footballs etc. Magnetic attachment would allow redeployment to different places on the vehicle and movement from vehicle to vehicle.

Liquid Filled Foliage

If artificial foliage is made from placing a liquid (such as water) in a plastic container shaped like the foliage of interest, one could selectively color the foliage in accordance with the current terrain by adding a few drops of dye to the liquid.



ARTIFICIAL FOLIAGE
AWAITING COLOR INJECTION

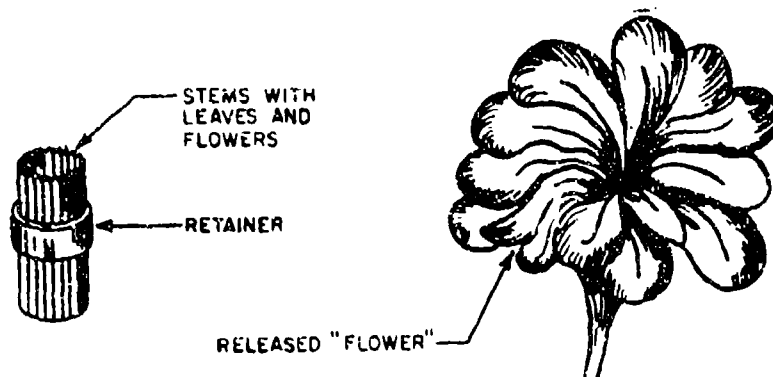


ARTIFICIAL FOLIAGE
WITH COLOR ADDED TO LIQUID

The foliage would take shape when filled with the liquid. This would allow the injection of the appropriate dyes. For multi-colored foliage, each branch could be compartmentalized. Draining the liquid would allow "deflation." Colored smoke may be used in place of the liquids.

Spring-loaded Foliage

Artificial flowers, bushes and the like can be compactly stored if they are made of thin wire with spring tension. Upon release of the springs, the bouquets would spread out and camouflage a significant portion of the equipment. Magnetic attaching points would be used.



The release mechanism could be as simple as a clip or as sophisticated as a remote system controllable from inside the vehicle.

Sophisticated systems could use electrical signals, compressed gas or mechanical release mechanisms to release the hook.

Foliage Kit

A construction kit could be designed such that the on-site personnel can readily design their own protective foliage. The component parts should be multi-sided (as hexagonal) with a slightly different shade painted on each side. Therefore, one has the ability to match his foliage with that of the background.



STEM



BRANCH



CONSTRUCTED

The component parts could be assembled as an artificial Christmas Tree. The kit could be compactly stored and stems could have magnetic attachments.

Foliage Preservatives

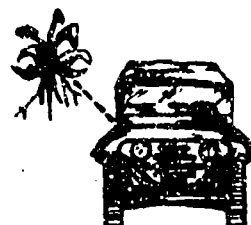
Florists use chemical dips to preserve flowers. Currently, foliage cut and mounted on equipment has a useful life expectancy of 4 hours. Florists are able to extend the life of their products for several days.



CUT FOLIAGE



TREAT WITH CHEMICALS

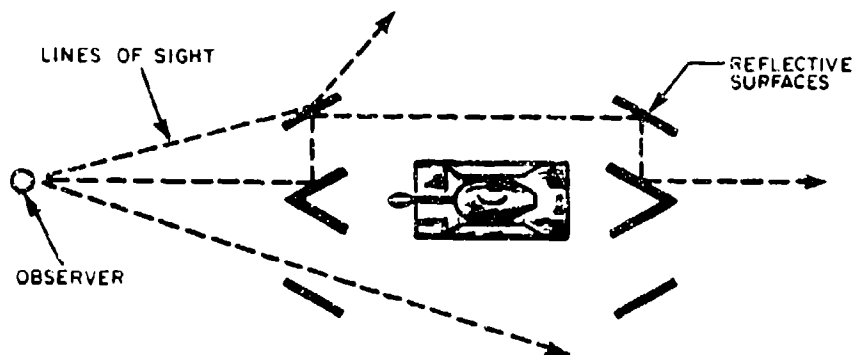


ATTACH TO EQUIPMENT

A spray can can be used to treat the stems. The use of real foliage has the obvious advantage of eliminating the need to carry cumbersome equipment. It also provides identical camouflage in respect to background. The sole disadvantage of this technique is barren scenarios.

Thru-Reflectance

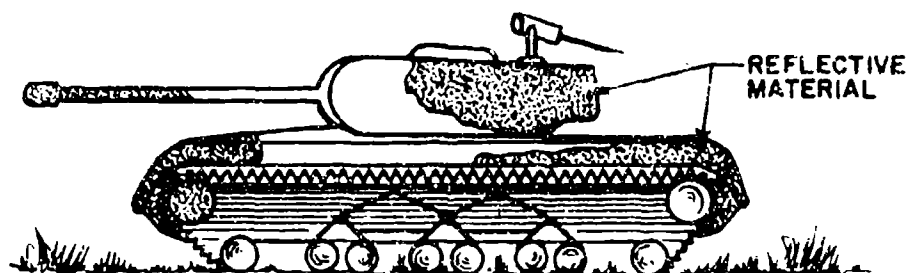
If an observer were approaching a piece of equipment, it could be completely camouflaged if mirrors were arranged such that his line of sight would be diverted around and out of back of item to be camouflaged As:



If all flat surfaces were mirrored finishes, the observers view would be directed around the tank and would have the effect of displaying to him the same view he would see if the tank did not exist. If the back surface of the front side mirrors were also reflective, the surrounding terrain would be reflective. Prior efforts have proven the feasibility of the reflective technique. The major problem is support structure for the reflective material. Inflatable approaches are most promising. A fiber optic periscope with fish eye lenses might eliminate the need for the reflective barriers.

Reflective Patches

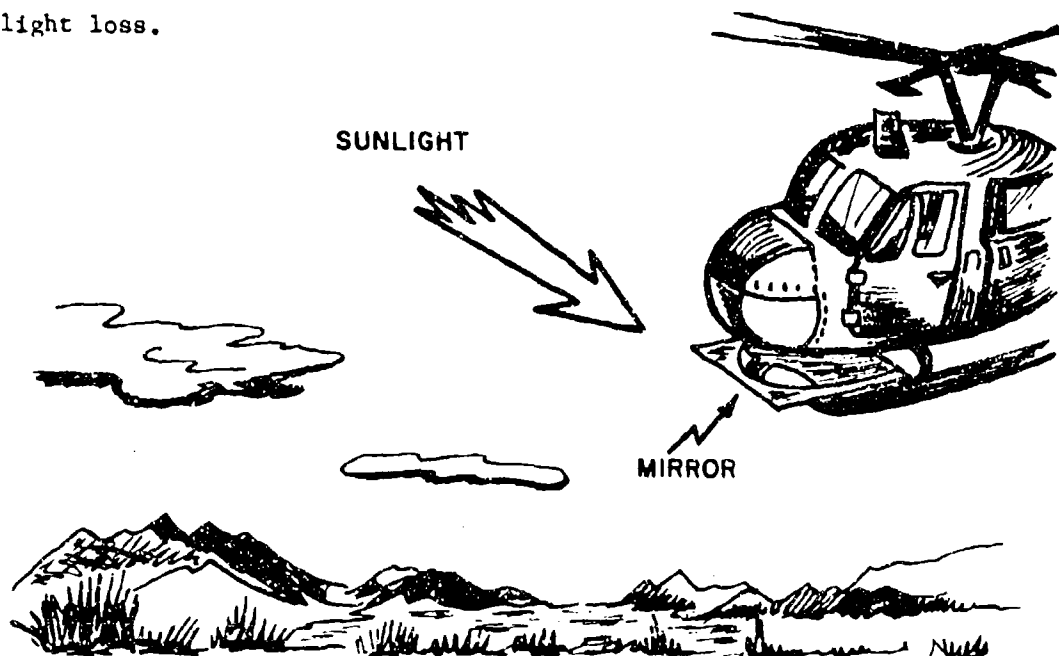
Reflective patches on strategic sections. That is, contour lines identify target. Use highly polished reflective metals in such areas as corners, gun barrels and in center of large masses, as:



Shaded areas indicate location of reflective material. Note: It cannot be located in planes which will reflect the sky. It is intended to be a partial solution and to break up contour lines. In a heavy foliaged area, it would have the effect of attaching foliage. In other terrains, it would reflect the proper images. Carried to an extreme, the entire vehicle would be reflective and designed to have all contours slanted groundward. The recommended solution is, as shown in the picture, applicable to all current equipment. It is also functional in a mobile mode.

Mirror Illuminates

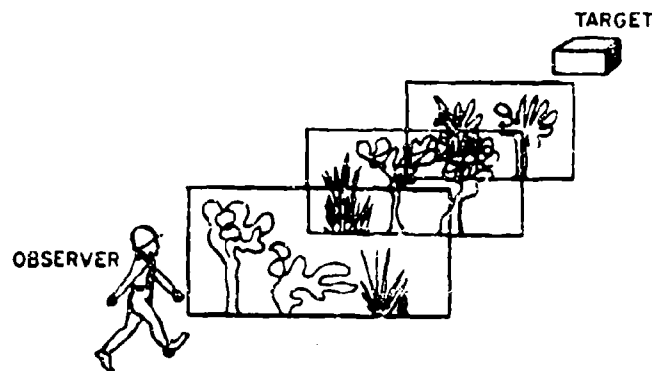
Detections affected by virtue of the fact that internal shadows provide a distinct contrast to the observer could be reduced by reflective surfaces aimed at redirecting the sun's rays at a negligible light loss.



On overcast days or at night, this form of detection is not as significant; therefore, absence of the sun's rays are an asset to camouflage. The reflective surface could be a host of different things. In the case of the tank, it probably should be mirrored on both sides or terrain camouflaged on the reverse. Improvements in the shape of the skids for the helicopter and highly reflective surfaces might suffice.

3-D Camouflage

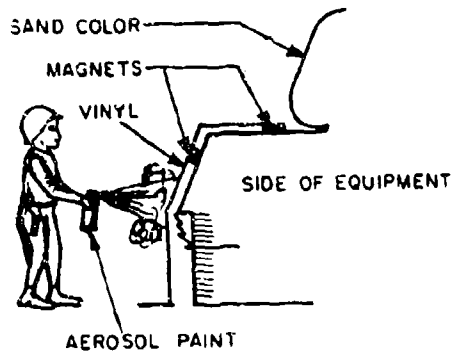
An array of barriers displaying partially transparent scenery would present a 3-dimensional image to the observer. The distances between the barriers would yield the effect and thus allow camouflage from very short distances. At close range, barriers are identifiable by their lack of movement.



The scene would take up some percentage of the barrier while the rest would be transparent to allow view of the scene behind. Permanent or field painted scenes, or camouflage netting would serve this purpose. Outpost emplacements would be ideally camouflaged in this manner. The observer would have to practically walk right into the barrier before he would become suspicious.

Transparent Shade

Rolled up translucent plastic which could be attached to the equipment by magnetism. The tank itself could be painted sand color for desert operation (ala Rommel). Spray cans could be used on the deployed plastic to gain camouflage for all terrains encountered.

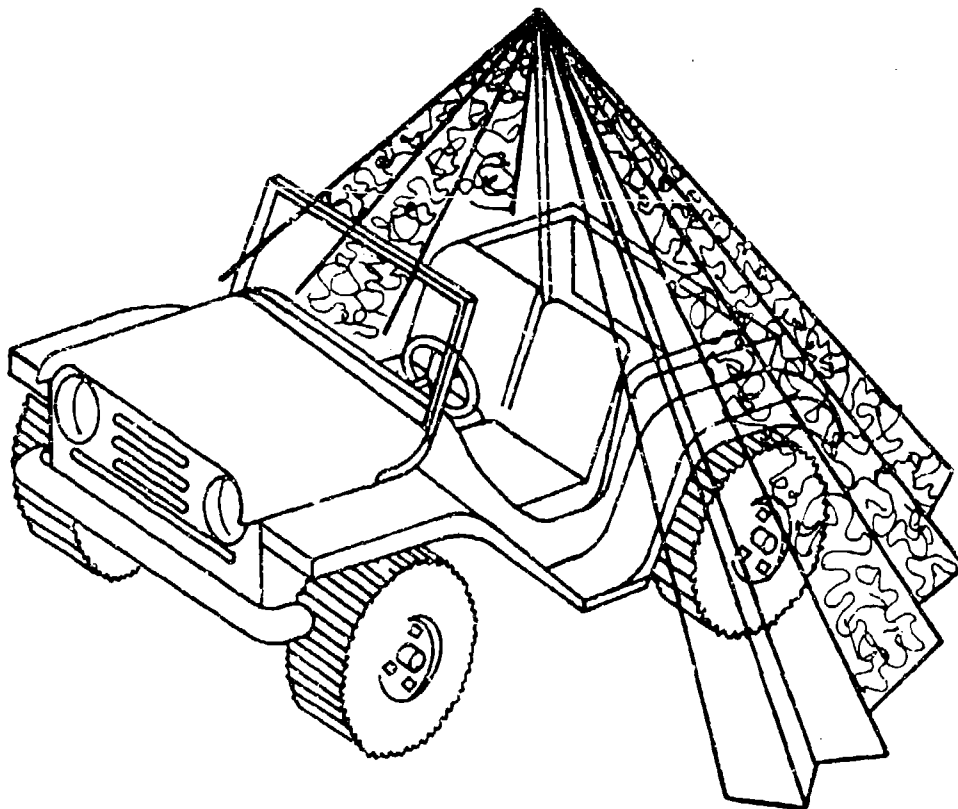


This type of camouflage would respond to the wind and would therefore blend in with the natural movements of the surrounding foliage.

The plastic could be spring loaded (as a window shade) for re-useability.

Fanfolded Barriers

The concept of a Japanese folding fan or a peacock's feathers could be utilized when equipment is camouflaged in a stationary mode. These barriers could be made of a "cut sheet"⁽¹⁾ design or a corrugated array. Deployment of the barrier could be accomplished by dropping it over the item to be hidden or leaning it against the superstructure. Motorized deployment techniques are applicable, but they complicate implementation and perhaps restricts use to certain vehicles.



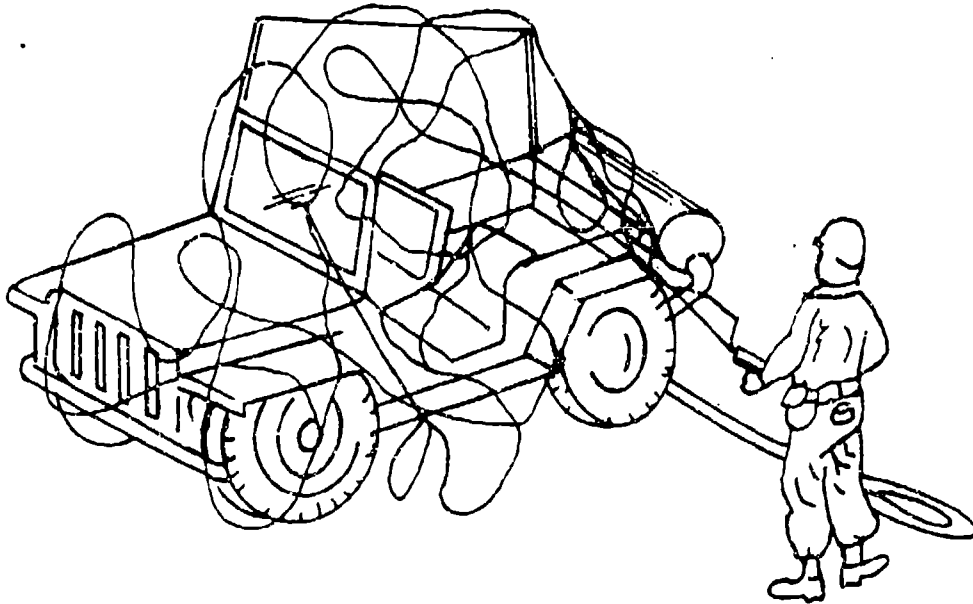
Unfolded, this camouflage could take advantage of color patterns (as marine uniforms) or could be designed for specific terrain.

Concertina wire could be employed to give a supporting structure for the material. The wire could be spring loaded for deployment or small explosive charges could propel the support wire over the equipment.

(1) See FIRC Camouflage Report - 1958 - Ed Thelen.

Silly String

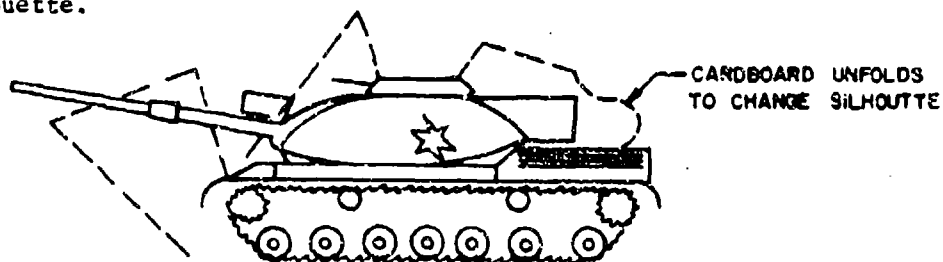
A tank of material (the size of a fire extinguisher) could be stored on the equipment for deployment as needed. This material could be similar to the child's popular "silly string." It would be either deployed directly on the equipment to be camouflaged or a series of telescopic poles could be deployed to support the "silly string."



The "silly string" could be colored as needed. It is extremely easy to scrape off when relocating. The poles would simply be retracted. If the string is deployed over the body of the vehicle, it would merely be pulled off.

Collapsible Housing

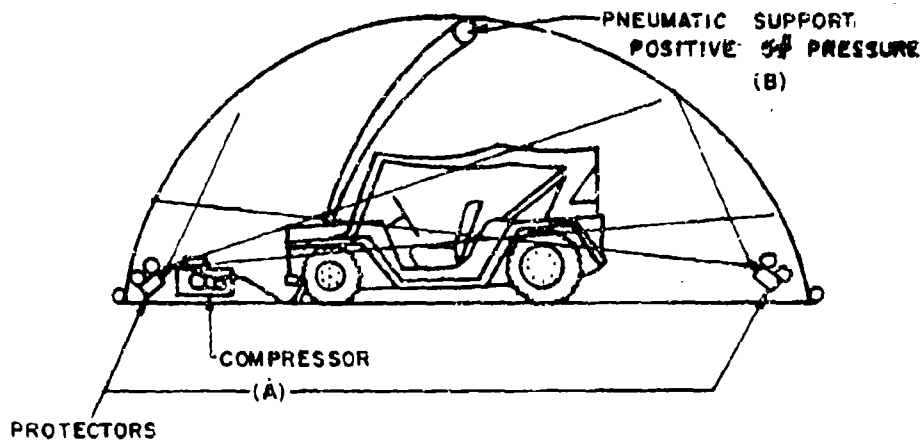
Lightweight material (even cardboard) could be used to construct various shapes to mount on the housing of the equipment to be camouflaged. It could be used to cover tell-tale shapes or perhaps to change the silhouette.



Panels could be made to snap together and to be expandable by telescoping features. The panels may even be constructed of irregular shapes as shown in the artists sketch on the rear portion of the tank.

Bubbles

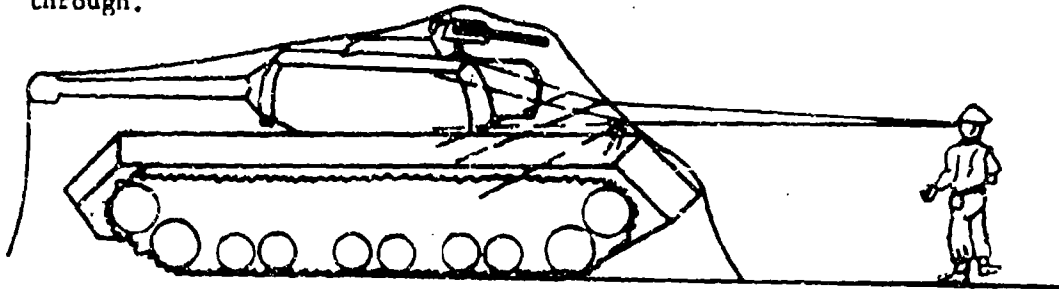
Vinyl bubbles, as those used over tennis courts, could be placed over the entire structure. Poles could support the structure or a compressor could maintain shape. Illumination inside the bubble could be used to generate a colored effect on the outside of the bubble. Other possible supports include helium filled balloons strategically located, a ribbed structure aided by lighter than air gases, a compressor to provide supporting pressure or an internal pocket of lighter than air gases to float above the natural atmosphere and support the structure.



(A) and (B) indicate alternate methods of support. Aside from support poles, a fourth potential is to use the equipment itself for support. A rib structure would aid in maintaining an irregular shape.

Distortion Cover

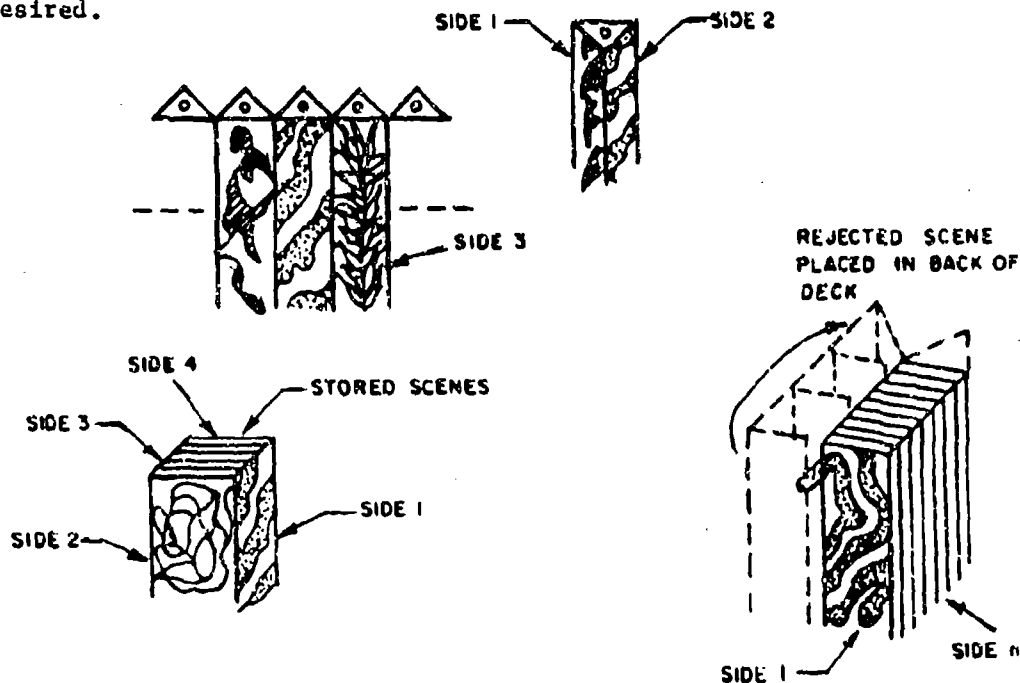
A spherical shell made of transparent material with a high refractive index could be hung over the item to be camouflaged in a loose fitting mode. This would divert and disrupt the light rays passing through.



The high refractive index would distort the image. The loose fit takes advantage of the old fashioned dresses which tended to camouflage whatever they covered.

Rotatable Billboards

Highway billboards have three-sided displays which rotate to present a changing picture to the motorist. Camouflage could use a multi-sided barrier of this type which would allow the user to use the scene desired.

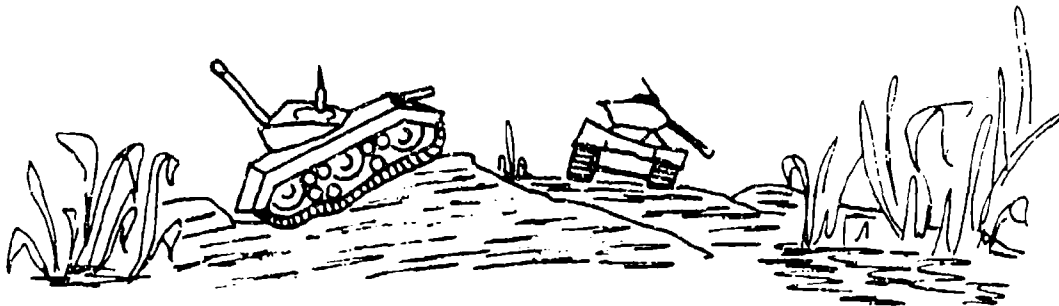


The various views presented can be color combinations of browns and greens. The particular display would be chosen by virtue of their compatibility with the environment. A four sided display would be the most efficient for manual scene selection. The four sided configuration could store alternate scenes within its structure.

Another method of multiple displays would be in a "book" form. The scene would be selected by flipping the pages from front to back.

Illogical Arrays

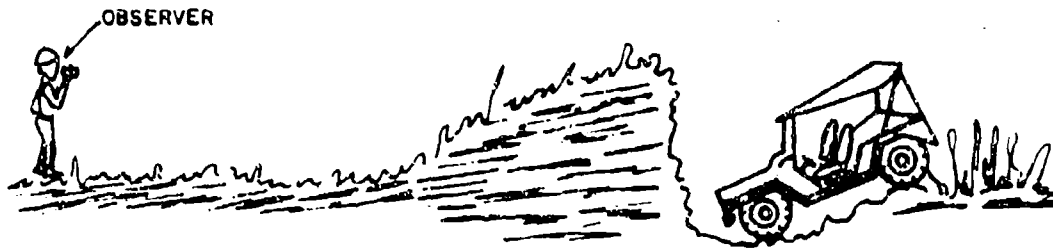
The concept of deploying equipment in illogical arrays has been known for years but is oft-times forgotten. This approach coupled with other camouflage techniques should be reviewed. For instance:



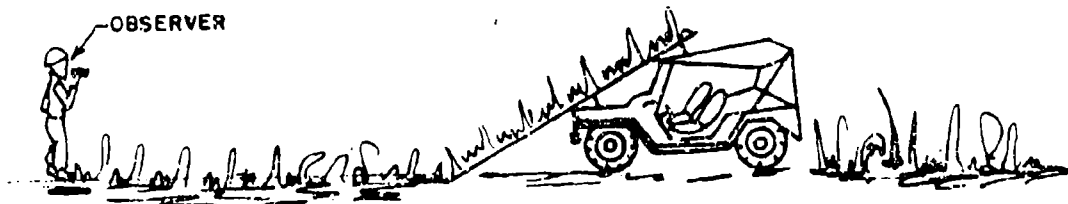
A tank parked with its gun facing straight up might be mistaken for a telephone pole with some other less dangerous equipment at its base. Anti-aircraft guns can be parked with their muzzles pointing downward or inside backs of trucks or across other parts of vehicles. These illogical arrays would be incorporated jointly with other techniques recommended.

Instant Hole

All camouflage techniques seem to be aimed at keeping surface equipment on the surface of the ground. If one were to dig a hole with a gradual slope, one could drive a jeep into the hole such that approaching foot observers would not detect it until they were very close.



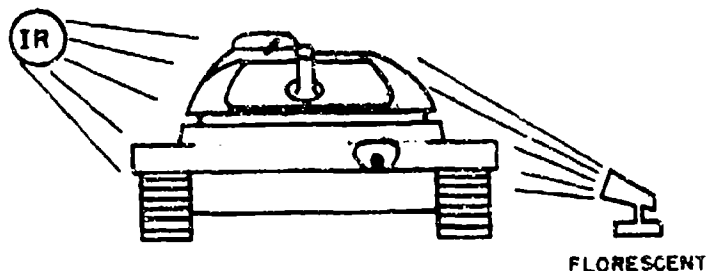
Demolition teams are expert at demolishing multi-storied buildings in metropolitan areas without harming adjacent building. Miners and excavationists have used the technique for years. It appears that strategically placed explosives could provide the field personnel with virtually "instant holes". Even if the hole did not cover the entire vehicle it would lower its silhouette. The Atomic Energy Commission are expert in this area. Also, if one could raise the earth in front of the equipment, the same effect would hold. Construction of a light lean-to framework with sod placed on it would suffice. A thin sheet of metal driven by the vehicle could plow up a blanket of earth to be included in front of the vehicle. This method has the advantage of using natural foliage that will remain alive (eliminating the need for preservation treatment).



A modification of the technique would be slicing strips of sod containing grass and small bushes and laying them on the item to be camouflaged. If the strips are deep enough, the foliage will not die (discolor).

Light Sensitive Paints

Certain paints change color when exposed to IR and almost all look different under florescent lighting as demonstrated by typical cocktail lounge lighting. With proper deployment of paints and/or lighting, one could fashion an effective camouflage.

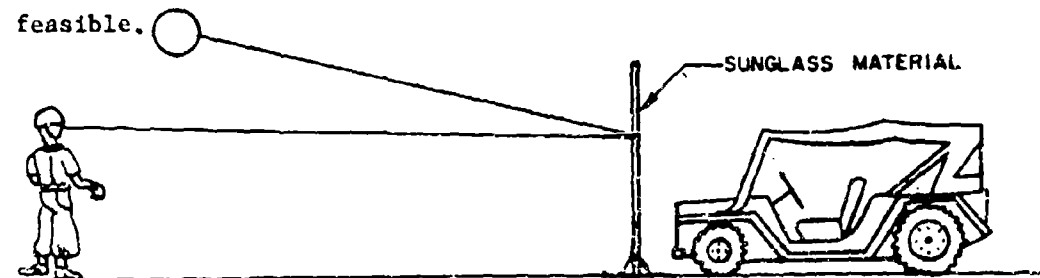


IR sensitive paints would be the ideal solution since they do not require support equipment. It is questionable as to whether they can be made to recover in the absence of light. Florescent lighting could be employed upon demand.

The technique of graduated color changes (dark at bottom-light at top) with wavy contour lines is applicable here as well as with normal camouflage paint.

Light Sensitive Materials

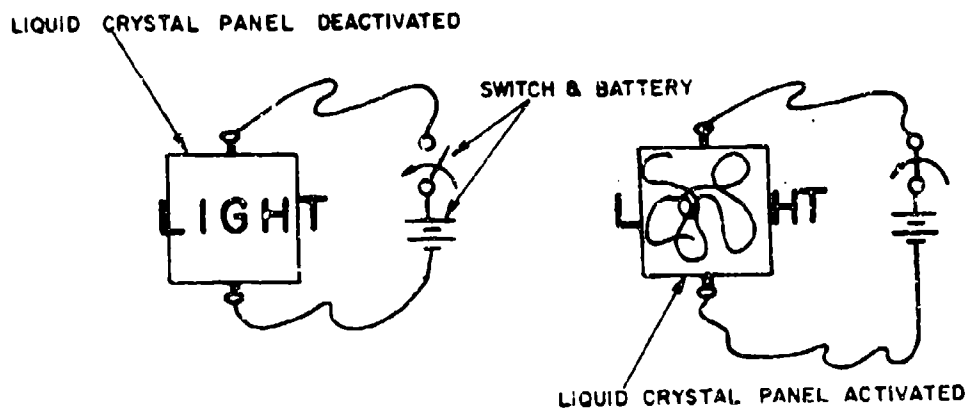
Modern sunglasses are capable of responding to increased light levels by turning darker. In general, this is the opposite effect desired in camouflage. Materials and chemical reactions necessary to provide this phenomenon must be studied to determine if the inverse is feasible.



In the standard configuration, the observer sees a dark area regardless of the sun's intensity. This would be useful in certain terrains, especially in those with low light level backgrounds (such as tree lined woods and forest backgrounds).

Temperature Sensitive Camouflage

Liquid crystals which are normally clear can be transformed into an opaque state by application of a small amount of electrical power.



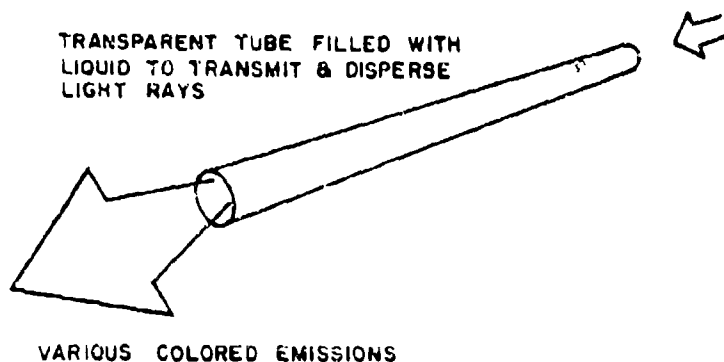
Voltage can be applied upon command. Crystals have been developed that are solids at room temperature and do not require a constant stimulus (e.g. electricity, heat). Other crystals respond with color change to a change in temperature. Browns and greens would be most desirable. The latter type would be most useful in an area with tall trees which would filter the light rays. The crystals are capable of responding to small changes in temperature. They have been used in mapping a temperature profile on the human body. Localized heat generated by operating equipment (such as motors, etc.) would enhance the effect.

Concepts involved in common color blind tests (that is, certain color combinations can be seen by some people but not by others), can be used in selecting combinations most conducive to camouflage.

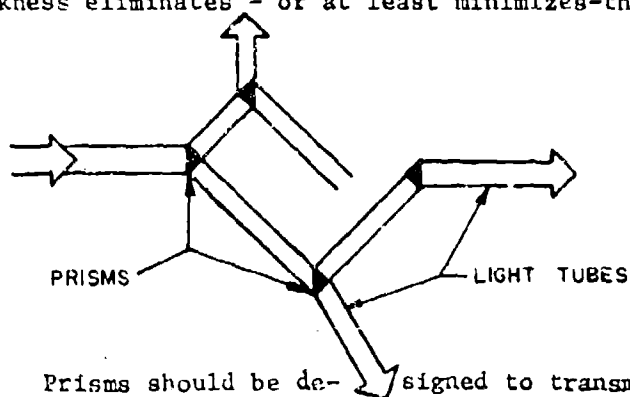
There exists temperature indicator paints which could be used in place of liquid crystals. Perhaps an addition of heat generating equipment strategically placed would provide proper color combinations. Materials that change color as a function of humidity have been developed and should be investigated in regard to camouflage.

Transparent Tubes with Prisms

Transparent panels or tubes filled with a colored liquid or controlled color changes by light pipes. Liquids would have the advantage of offering polarizing capabilities.



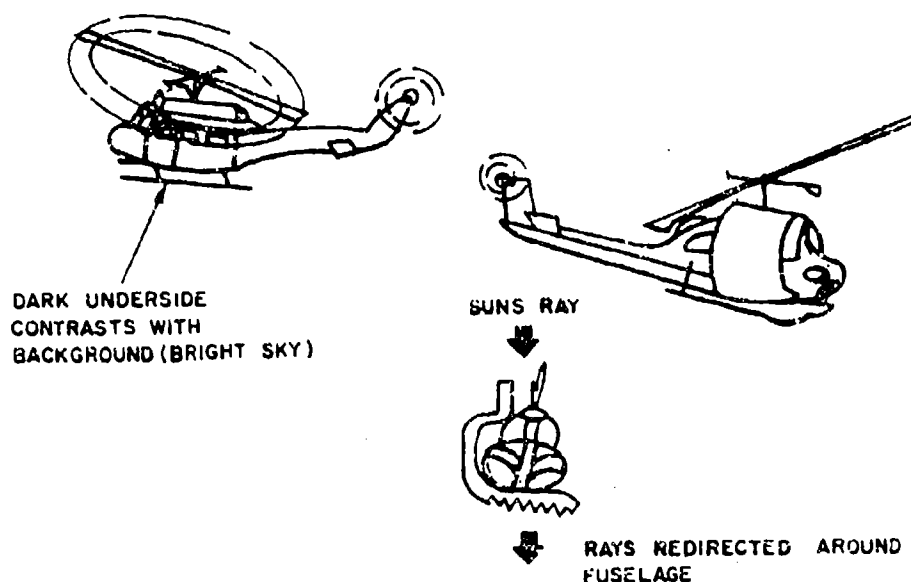
Tubes or other light conducting media (as panels) could be strategically located around the equipment. By a predetermined program or on command, a constant or variable light array could be emitted. Some equipment may dictate steady light while others (like mobile units) may dictate controllable colors. The ultimate system may be a matrix array with properly designed prisms at the junctions. This has the advantage of not needing operator intervention. It could use sunlight (Darkness eliminates - or at least minimizes-the need for camouflage).



Prisms should be designed to transmit shades of green and brown (tans for desert environments). This system could be applied to current equipment and built into future designs. The matrix with prism junctions is a passive system.

Light Pipes

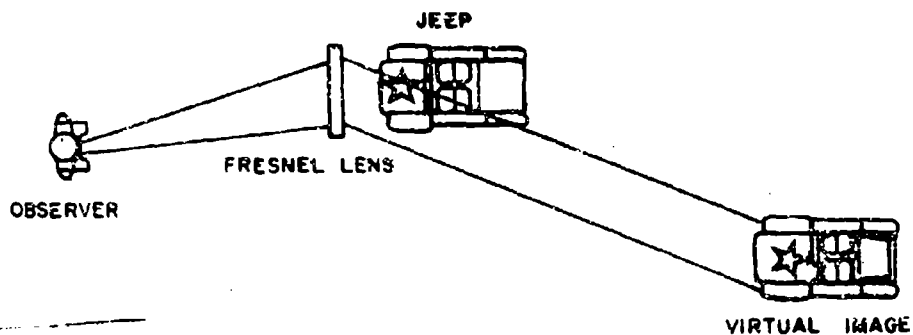
Thin plastic films could be added to the surface of aircraft in order to redirect the intense light rays from above to the undersurface of the aircraft in order to illuminate the bottom.



Thin films would not significantly hinder the aircraft's performance. An interface system which will absorb the rays and direct them downward into the film is essential. The rays would be allowed to emanate from the undersurface so that the observer sees bright light all around.

Fresnel Lens

Fresnel lenses have interesting optical characteristics. They are capable of presenting a virtual image to the observer which could be displaced from the target area by large distances.

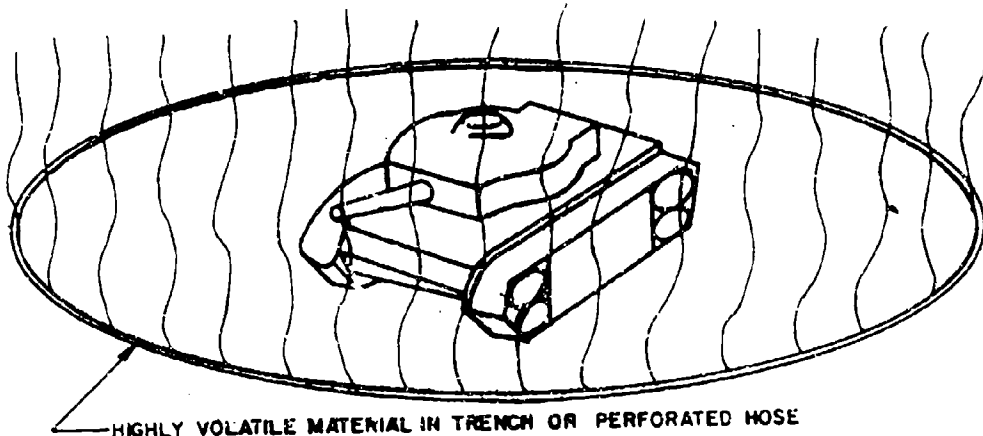


This technique is used to aid pilots in landing on aircraft carriers. The virtual image could be used as a decoy to draw attention away from the target of interest. The Fresnel lens need not obscure the entire target if it successfully diverts attention. Perhaps, a fish eye lens in conjunction with the Fresnel would prove useful.

If a Fresnel lens were cut into pieces, one could create a kaleidoscopic effect. The F.I. museum has an example of the capability of mixing images with flat glasses (search light exhibit).

Vapor Distortion

On a very warm day, one can see heat waves rising from roads. The effect of this phenomenon is that a distorted image is perceived. If one could artificially create this occurrence upon command, an effective screen could be made.

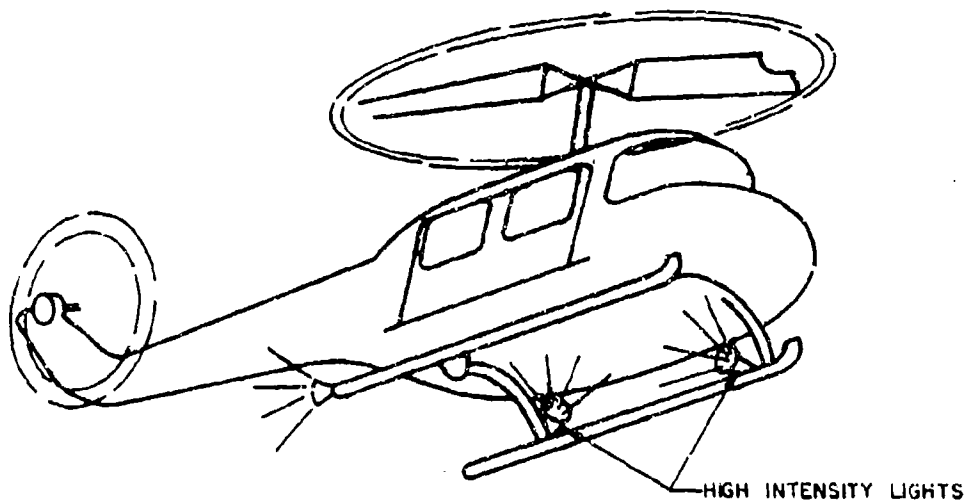


A circular ring placed around item to be camouflaged could be supplied with a liquid with a low vapor pressure. Heat or other catalysts would boil the liquid which would emit the distortion screen.

Proper control of the vapors could cause various effects such as "looming" (causes item to seem to be elevated due to a change in index of refraction) or could distort beyond recognition.

Floodlamps

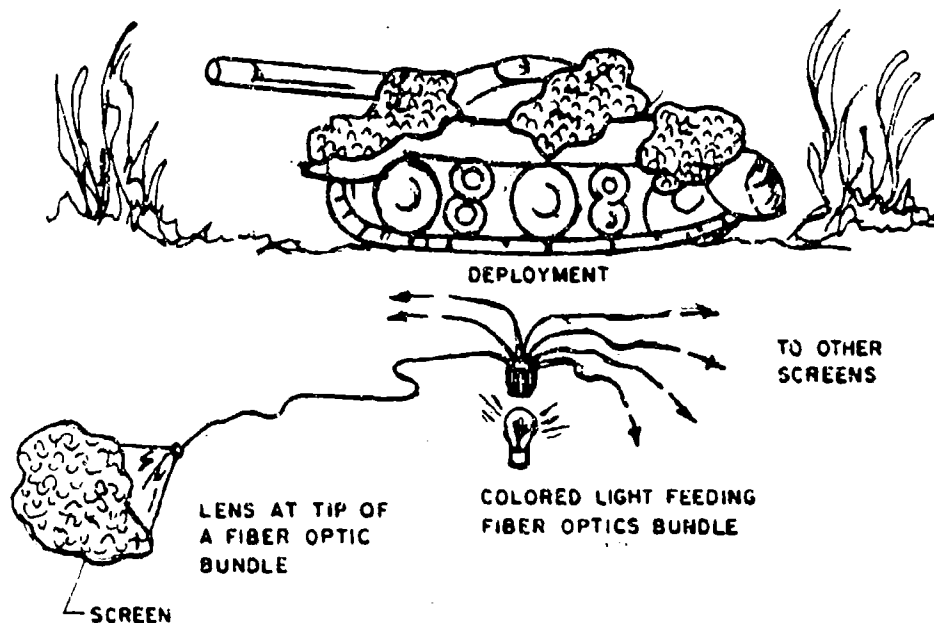
A helicopter presents an ideal format for using high power flood lamps to eliminate contrast detection. The lamps can be mounted on the skids and powered by the helicopter's electrical system.



A sophisticated system could use a light meter mounted atop the aircraft which would adjust the light intensity in accordance with background intensity.

Color Light Transports

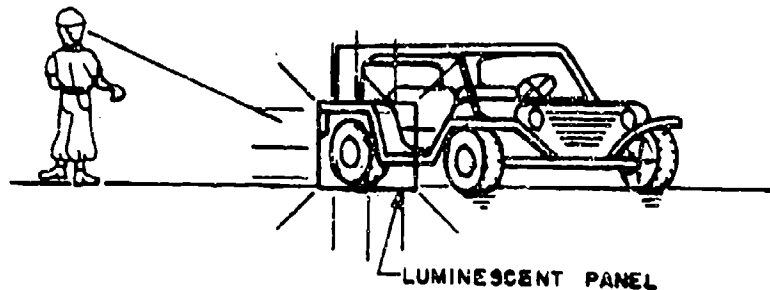
A coarse bundle of incoherent fiber optics with proper lenses could be used to transmit light colors from inside the equipment to the outside.



The screen could be small flat sections (or slightly curved) slightly misaligned with their neighbor. Proper prism output would present various shades to the observer. Perhaps proper coloring of the screen backlit by white light would be applicable. A chopped rotating flasher mounted atop a vehicle, fed images by a fiber optic bundle, could give off multi-directional images aimed at confusing the observer.

Luminescent Panels

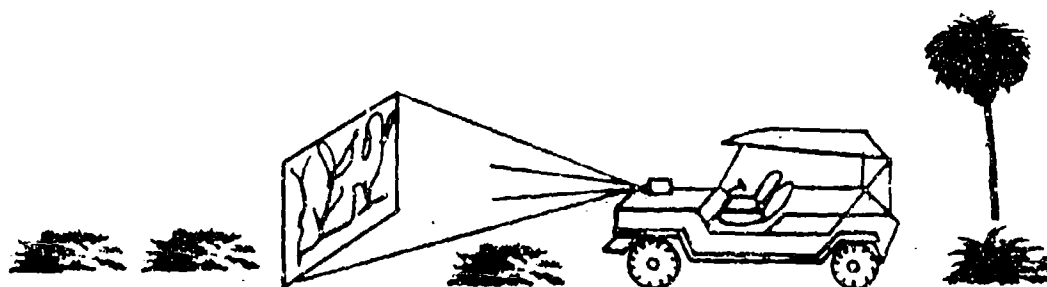
Electro-luminescent panels could be used to eliminate included shadow-contrast detection. These panels have proven to be inadequate on aircraft because they cannot generate sufficient power. The relatively dark background encountered on the ground would be conducive to this approach.



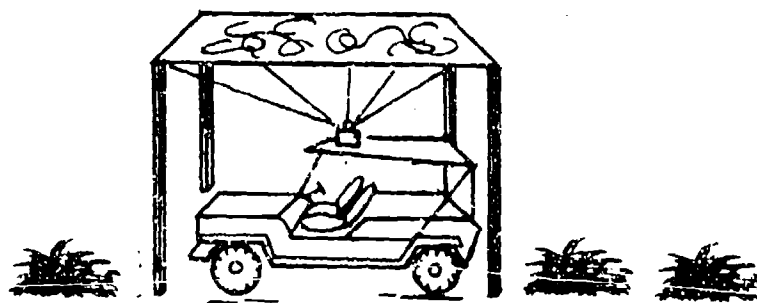
The electro luminescent panels are activated upon command in response to terrain, sun angle and threat of detection.

Slide Projections

A polaroid picture of the terrain could be processed and utilized in a projector. A screen in front of the equipment to be camouflaged would present the image to the observer.



This concept could be extended to encircle the equipment. It would also be applicable to anti-aerial observations.



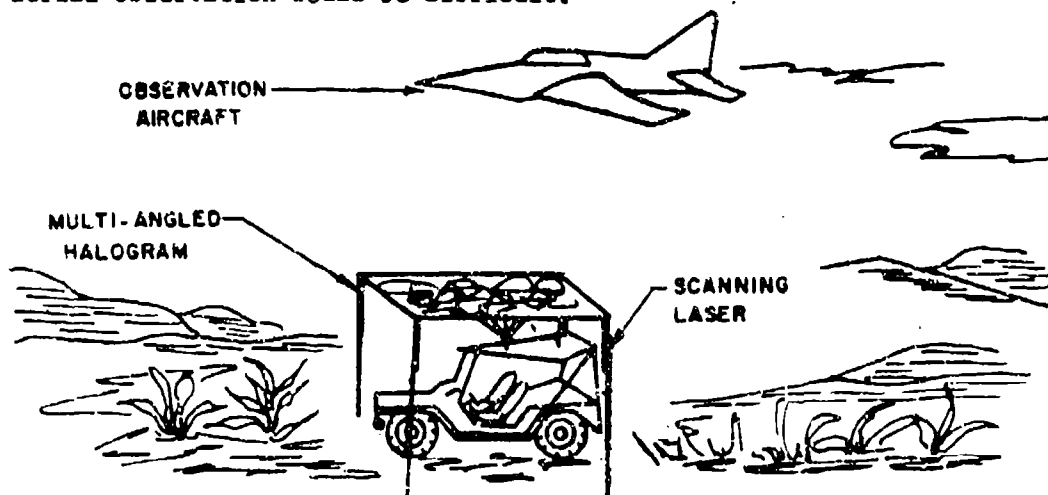
In its final form, the screen could be mounted on the equipment and a special wide angle fish eye lens on the projector would yield the necessary picture format.

The projector may also be placed away from the equipment to be hidden. The screen could be of flexible material which would give motion to the image projected.

The screen could possibly be replaced by a thin smoke film generated by a slow releasing smoke grenade. This smoke screen could be any color. Colored smoke would allow use of black and white slides which would, of course, be easier to facilitate processing in the field.

Halograms

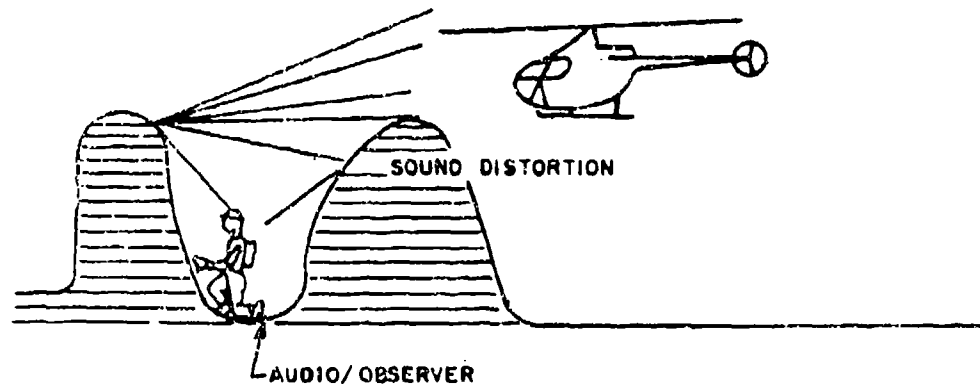
Halograms are used to present different images in different planes. If a multi-faceted halogram could be displayed above a ground target, aerial observation would be difficult.



A halogram is displayed over an angle of $1/2$ degree. An airplane at a reasonable altitude would travel a significant distance within this $1/2$ degree cone. A family of halograms would protect the equipment over a wide range. A moving screen would be needed to accomplish this aim, or a scanning laser.

Sound Camouflage

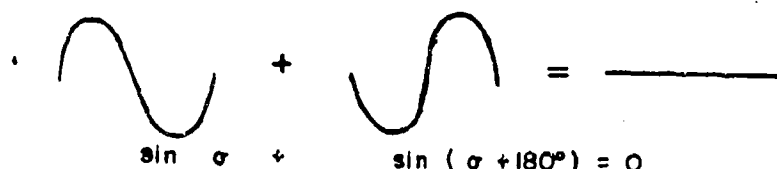
Oft-times, sounds give away the position of a motorized piece of equipment. On the other hand, sounds can be deceiving. For instance, a helicopter flying low over tall buildings can appear to be in a different position due to sound waves reflecting from buildings. The same is true when a helicopter flies nap of the earth in hilly regions.



This phenomenon can be taken advantage of by masking the true sound with decay sounds. For instance, a loud speaker mounted on a helicopter could be producing sounds of a convoy of trucks or tanks. The converse is also true, of course. Perhaps the sound of wind or thunder would serve as complete sound camouflage. Bird or animal sounds are also potential solutions.

Negative Sound

Theoretically, any sound can be completely eliminated by the generation of sound waves which are negative in polarity, but otherwise exact duplicates of the original sound. The simplest example of this phenomenon is the Algebraic addition of two sine waves, each 180° out of phase with the other.


$$\sin \sigma + \sin (\sigma + 180^\circ) = 0$$

Negative sound can be produced electronically through microphone, amplifiers, inverter and speaker. Practical problems in generating negative noise include phase shifting due to electronic lag. Also to exactly duplicate (inverter) the original sound, the negative noise must originate from the exact position of the original sound source. These problems result in an interference pattern between the two sound sources which will allow the sounds to be heard in certain areas, however, in other areas, the sounds waves add peak to valley and are completely eliminated.

With complex noise, in a particular dull spot, only certain frequencies will be eliminated. While this will not eliminate sound completely, it will camouflage it by frequency distortion.

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